Effects of Biota on Backscatter: Experiments with the Portable Acoustic Laboratory (PAL)

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LONG-TERM GOALS

Our long-term goals are to understand — to an extent that allows quantitative prediction — important interactions among acoustic propagation, marine organisms, particles (including sediments), solutes and moving fluids. The reason for these goals is to allow us to solve interesting forward and inverse problems in the marine environment.

OBJECTIVES

The objective of this work is to develop a rapidly deployable, inexpensive capability to do reductionist, mechanistic experiments concerning the effects of organisms, biogenic structures and benthic structures in general on acoustic propagation in sediments.

APPROACH

The underlying concept of this work is that one of the limitations on progress in understanding acoustic propagation, particularly at low angles of incidence with the sediment-water interface, is the lack of a laboratory facility that can realistically accommodate biological processes that may be important in affecting acoustic propagation. The primary means currently available to test ideas about biological effects on propagation is as projects embedded in episodic and expensive field experiments that require ship time and deployment configurations that are difficult to change "on the fly." An indoor laboratory cannot easily remove this impediment to research progress for many reasons, some of which are acoustic and some biological. Particularly at low angles with the seabed, echoes in laboratory tanks are acute problems. Another major issue in laboratory facilities is the formation or inclusion of gas bubbles in the sedimentary matrix. Yet another is the rapid degradation of "chunks" of the ecosystem brought into the laboratory to represent the natural system.

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To circumvent many of these difficulties, we have developed the concept of a portable field laboratory (PAL), a set of observational tools that can "plug and play" wherever there is a source of power into and a conduit for information out from the sea. One of the assets of such an experimental facility is a known fauna and sedimentary structure, so a logical initial target is the end of the pier at an existing marine laboratory, and we have begun at the Friday Harbor Laboratories of the University of Washington. The assets are portable, however, and can be moved to another marine laboratory, or arbitrary shore site, and this facility represents one kind of package that might be plugged into future networks of benthic marine observatories.

Our first field test will be to aim the system at the bottom through a volume of water that is also ensonified by a TAPS-6 instrument designed by Van Holliday of BAE Systems in San Diego. It is a 6-frequency backscatter system. A problem with interpretation of 300 kHz field data at low grazing angle has been to resolve the backscatter from intervening volume reverberation (near-seabed plankton or so-called demersal or hyperbenthic fauna) versus from the seabed. The TAPS-6 geometry will be arranged to return little or no signal from the seabed, so we will get interleaved records that include little or no benthos (TAPS-6) and that include both (tripod) to aid in developing algorithms for removing the planktonic signal from the tripod's output. Simultaneous stereophotography will aid in resolving the tripod output components due to changing surface microtopography.

Our second field test will be to produce a layered bed of 1 cm of sand overlying mud to test the prediction that backscatter will first increase due to both surface microtopography and volume heterogeneity produced in the sediments by bioturbating animals before falling again as continued bioturbation homogenizes the mixed bed. We are testing the basic scenario of bioturbation as layered bedding followed by "mottles" followed by a mixed bed, but placing it in an acoustic context. Simultaneous stereo photography will help to extract the component of these effects that is due to time-varying surficial microtopography.

WORK COMPLETED

Our first feasibility test, prior to the current grant, was of a pier-mounted, hand-steered 300 kHz transducer mounted on the pier pilings at Friday Harbor Laboratories. The purpose was to test whether the noise environment (both pier electrical and underwater sound field) and mixed sedimentary environment permitted resolution of backscattering targets on the seabed. Positive results set us on the way toward the current system.

We have moved to a tripod geometry, with automated steering of acoustic transducers for ease of deployment and versatility in responding to experimental situations. There are many advantages to using more than a single frequency, and we have moved to a two-frequency system at 120 and 300 kHz. A PAR sensor and underwater video camera complete the current configuration of the tripod.

A separate frame houses a digital stereo camera. This system has been built from components rather than off the shelf to take advantage of recent improvements in pixel resolution in particular and digital technology in general.

The system is integrated with a PC controller and has been deployed off the APL pier on Lake Union. It is being readied for an October-November 2000 deployment with TAPS-6 at the Friday Harbor Laboratories pier. The delay from the planned deployment in summer 2000 has come from unanticipated delays in procurement of components.

RESULTS

Even before the delay, we had planned to use historical data as well as our own to identify promising algorithms for separating benthic from planktonic components of the backscatter signal. Toward that end, we have been examining 5 yr of 300-kHz, upward-looking, range-gated ADCP data from the STRATAFORM program off the Eel River in northern California and comparing them with time series of records taken by BAMS and XBAMS also as part of that program. In addition, we have several backscatter time series from BAMS and XBAMS from other locations at both 300 and 40 kHz. To date all the BAMS and XBAMS time series of backscatter require full ARIMA (AutoRegressive Integrated Moving Average) models to fit the time series well, whereas the uplooking ADCP data that carry only a planktonic (volume reverberation) signal can be fitted by a simple AR (autoregressive) model. We are intrigued by the possibility that benthic time series may have essential differences from planktonic ones and are looking into mechanistic explanations.

IMPACT/APPLICATION

We anticipate that this kind of portable field laboratory will be useful for answering many specific questions about potential biological effects on backscatter. For example, in the benign setting of a field laboratory, it is feasible to deploy mine-like objects and monitor how their acoustic signatures change as organisms foul their exposed surfaces and bioturbation and perhaps geochemical processes alter their acoustic coupling with overlying water and underlying sediments.

RELATED PROJECTS

This work is a collaboration between Chris Jones of the Applied Physics Laboratory, University of Washington, and Pete Jumars of the University of Maine. The project was initiated when Pete Jumars was at the University of Washington, and the Director of the School of Oceanography, Bruce Frost, has become the titular Principal Investigator of the University of Washington component while Pete Jumars is the PI of the University of Maine component. The titles and texts of these two grants (N00014-00-1-0034 and -0035) are identical.

1 — This project is closely related to the ONR DRI on High-Frequency Sound Interaction in Ocean Sediments (coordinated by Eric Thorsos of the Applied Physics Laboratory of the University of Washington). Evolving details can be found at <http://www.apl.washington.edu/hfsa-dri/Program/prog.html>.

2 — Under separate funding, Pete Jumars at the University of Maine is also working with the related phenomenon of emergence by seabed fauna that may influence both surface microtopography and volume heterogeneity. This complementary grant is entitled “Shallow Scattering Layer (SSL): Emergence Behaviors of Coastal Macrofauna” (N00014-00-1-0662)

REFERENCE

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